Structural and Vibration Analysis of propeller blade in small aircraft

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Abstract - *Propeller blade is a major part of the aircraft. The main function of a propeller in the design of small aircraft is to convert the power delivered by an engine into propulsive thrust in order to propel an aircraft. This is achieved by acceleration of large mass of air backwards there by producing forward thrust. Materials should sustain the loading conditions and should be light weight as well.The objective of this study is to evaluate the strength and vibration characteristics of the Propeller blade design for metal and composite material. Also compare the performance under different operating loading conditions.*

The objective is to assess the quality and vibration attributes of the propeller cutting edge structure for metal (Aluminum) and composite material (Carbon UD epoxy). We will in general understand the action of load on the sharp edge with the goal that the varieties of stress are effortlessly noted through the product. The principle utilization of the ABAQUS programming is to upgrade the investigation level with the end goal to ad lib the heap conveying limit of the sharp edge. Additionally think about the execution under various working stacking conditions.

Key Words: Aluminum alloy and Carbon ud epoxy, stress analysis, Modal analysis, Finite element analysis

1. INTRODUCTION

Vibration is the motion which repeats itself after certain interval of time. Displacing from the position of equilibrium, it is the motion of a particle/body/system of connected bodies. When a system is displaced from a position of stable equilibrium, vibration occurs. If forces are applied, it returns to its original position after vibrating.

Vibration is a mechanical phenomenon whereby motions happen on a balance point. At the point when flexible bodies, for example, springs, a pillar and a pole are uprooted from the balance position by the utilization of outer powers and after that released, they execute vibratory movement. This is because of, when a body is uprooted the inside powers convey the body to its unique position. At the point when the body achieves the balance position entire of the strain or versatile vitality changed over into motor vitality because of which body keeps on moving the other way. The entire of the dynamic vitality is again changed over into strain vitality because of which body again comes back to the harmony position along these lines, vibratory movement is rehashed inconclusively. The vibration cause quick wear in machine parts, for example, direction and apparatuses. Thus, unwanted vibrations ought to be killed or diminish up to certain degree.

2. METHODOLOGY

Create Propeller blade 3D model using SOLID EDGE. Import to ABAQUS/CAE and mesh the model using Tetra elements. Perform stress and vibration analysis using ABAQUS/standard solver for metal and composite material. Perform stress analysis for different materials under loading conditions. Perform modal analysis for the same in order to get the values for metal and composite material. Obtain the results for maximum displacement and maximum stress involved. Find out the bending moment and twisting moment for different modes. The accurate results are obtained by trailing the loads and boundary conditions. The final values are noted and concluded.

2.1 Material Property

Table -1: Material Property for Aluminum alloy A6061

Property	Value	Unit
Density	2700	Kg/m³
Young's Modulus	70	GPa
Poisson's Ratio	0.33	
Tensile strength	280	MPa

Table -2: Material Property for composite carbon UD epoxy

Property		Value	Unit
Density		1600	Kg/m³
Young's Modulus	E11	142	GPa
	E22	10	GPa
	E33	10	GPa
Nusselt number	Nu 12	0.16	
	Nu 23	0.2	
	Nu 13	0.16	
Rigidity Modulus	G12	5.2	GPa
	G23	3.8	GPa
	G13	6	GPa

2.2 Geometric modeling

Fig -1: 3D Model of Propeller Blade

The first step in the analysis part is to prepare the 3-D model of the component/propeller blade. The structure of the propeller blade is made into 3-D as shown in the fig. above.

2.3 Import to ABAQUS and mesh the model using Tetra elements

Fig -2: Meshed part of the propeller blade

After the 3-D model of the component, import it to the analysis software, for example, ANSYS, ABAQUS. After importing, it is the necessary step to mesh it. The meshed component is shown fig 2.

2.4 Meshing

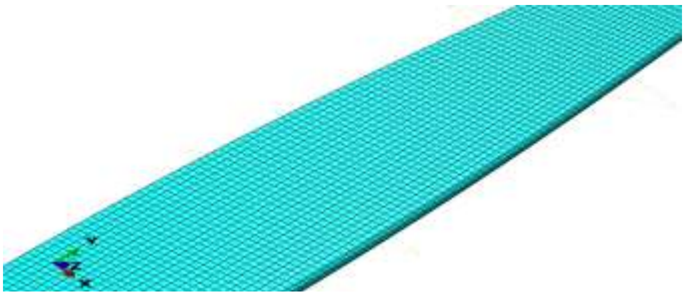


Fig -3: Meshing

After the meshing part, the detailed content of the propeller blade is given below. Total number of nodes: 148934. Total numbers of elements: 55163. There are 20125 quadratic hexahedral elements of type C3D20R. There are 1127 quadratic wedge elements of type C3D15. There are 33911 quadratic tetrahedral elements of type C3D10.

2.5 Perform stress analysis for different loading conditions

Fig -4: Modeling for FE Analysis / Finite Element Model of Propeller Blade

2.6 Loads and Boundary conditions

After meshing, the loads are applied at the ends of the blade. Applying loads on 'y' direction gives better results compared to x and z axis. At the one end, the rotational force is applied of about 2500rpm. On the other end, the blade is fixed as shown in the above figure. At the middle, the thrust is applied (22kN) as load input for the balancing condition. The stresses are acting maximum on the middle of the blade as the one end is fixed and other end is having little stress on it, so maximum stresses can be seen on the center part of the blade.

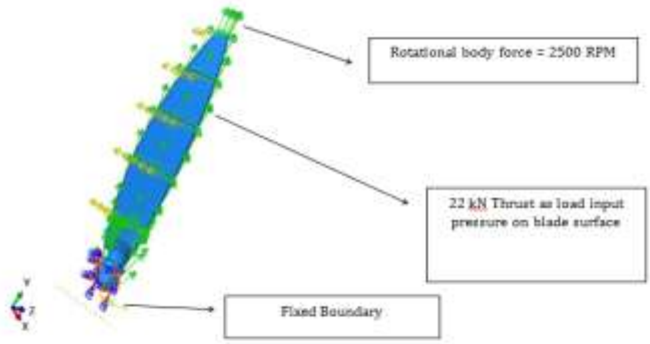


Fig -5: loads and boundary condition

3. RESULTS

3.1 Maximum displacement on blade and comparison

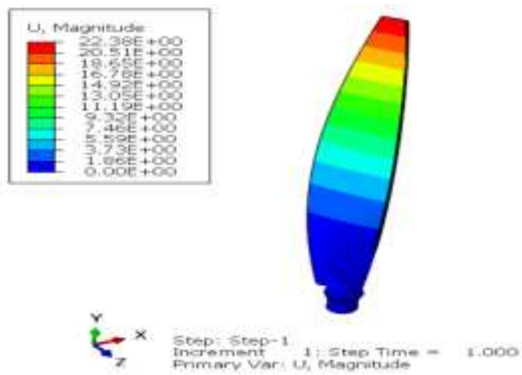


Fig -6: Maximum displacement of blade for aluminum

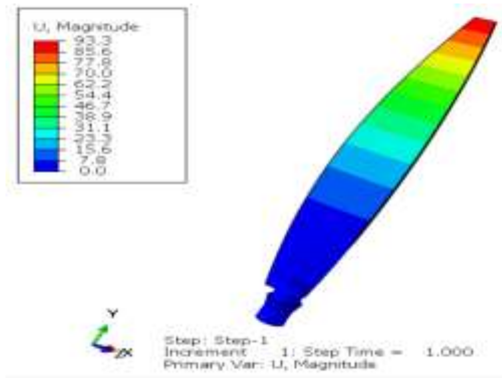


Fig -7: Maximum displacement of blade for carbon ud epoxy

The maximum displacement along X, Y and Z axis whereas X is undergoing a maximum value of 22.38mm, Z value is 0 and Y is the mean value is 13.05mm for aluminum. The displacements are varied along the entire axis. The maximum displacement along X, Y and Z axis whereas X is undergoing a maximum value of 93.33mm, Z value is 0 and Y is the mean value is 54.4mm for epoxy. The displacements are varied along the entire axis. The maximum displacement is more in composite material than aluminum

3.2 Maximum stresses on blade and comparison

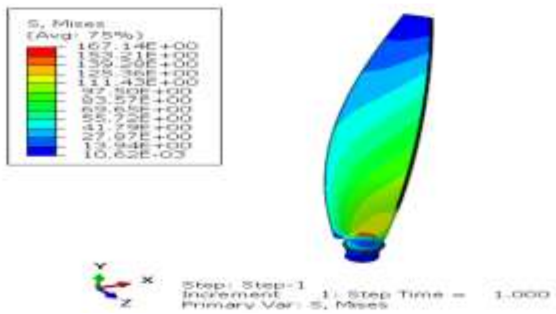


Fig -8: Maximum Stress of blade for aluminum

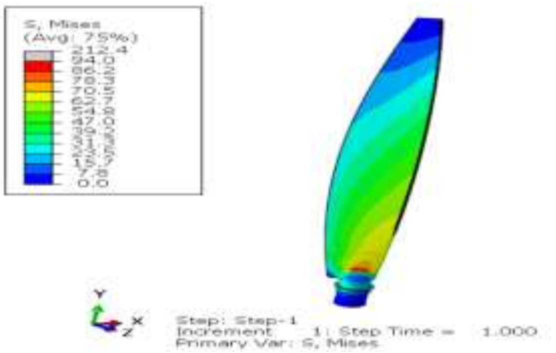
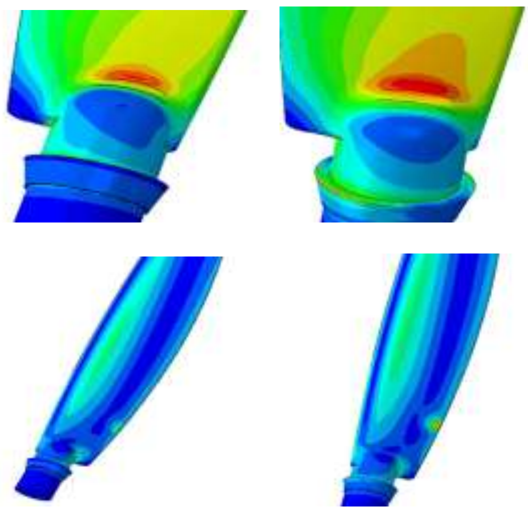


Fig -9: Maximum Stress of blade for carbon ud epoxy

The maximum stresses for aluminum can be seen in X direction which consists of 167MPa whereas Y axis and Z axis get 83.57MPa and 10.62MPa when the loads are applied respectively. The maximum stresses for aluminum can be seen in X direction which consists of 94MPa whereas Y axis and Z axis get 62.7MPa and 0MPa when the loads are applied respectively.

3.3 Comparison of blades between Aluminum & Composite



Aluminum Carbon ud epoxy

Fig -10: Comparison between Aluminum and Carbon ud epoxy

A comparison between the aluminum and composite for propeller blade has been given in the above diagrams. It is found that the maximum displacement and is 22mm and 93mm, maximum stress is 167Mpa and 94Mpa respectively in metal (aluminum) and composite (Carbon ud epoxy)

3.4 Modal analysis of propeller blade and comparison for Mode 1

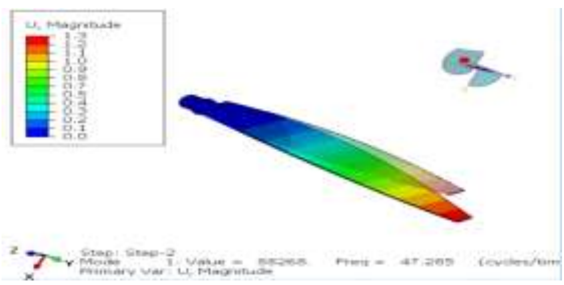


Fig -11: Aluminum Mode 1: 47.3 Hz, 1st Bending mode

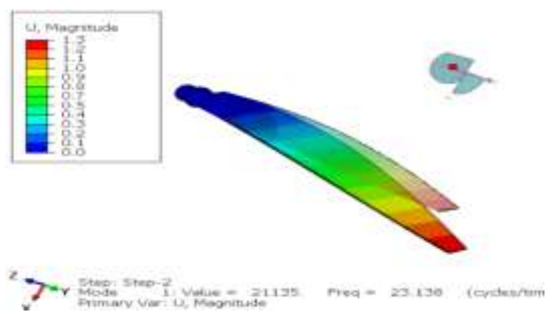


Fig -12: Carbon ud epoxy Mode 1:23.1 Hz, 1st Bending mode

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3.5 Modal analysis of propeller blade and comparison for Mode 2

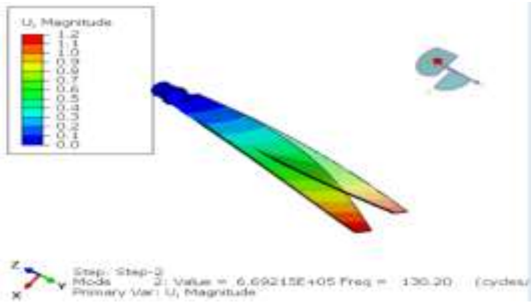

Fig -13: Aluminum Mode 2: 130.2 Hz, 1st Horizontal Bending mode

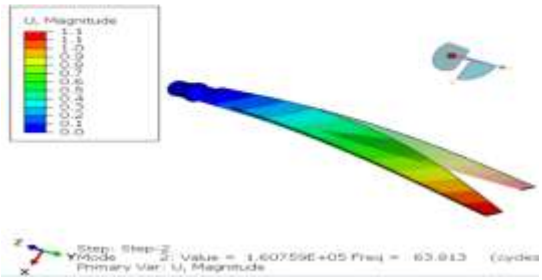

Fig -14: Carbon ud epoxy Mode 2:63.8 Hz, 1st Horizontal Bending mode

3.6 Modal analysis of propeller blade and comparison for Mode 3

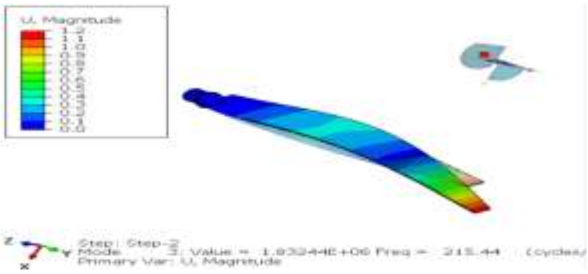

Fig -15: Aluminum Mode 3:215.4 Hz, 2nd Bending mode

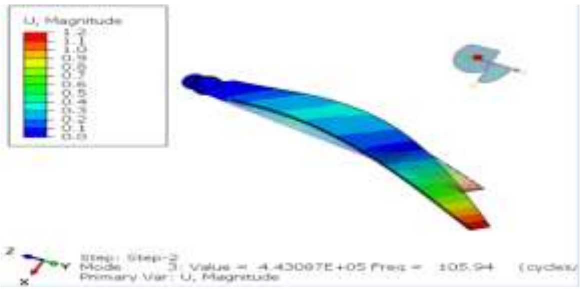

Fig -16: Carbon ud epoxy Mode 3:105.9 Hz, 2nd Bending mode

3.7 Modal analysis of propeller blade and comparison for Mode 4

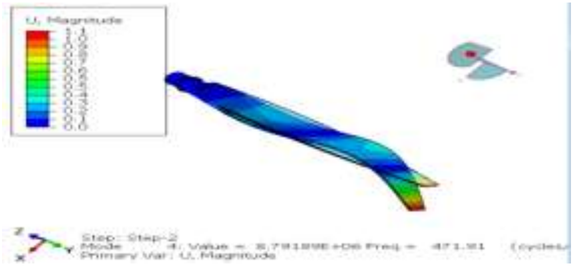

Fig -17: Aluminum Mode 4:471.9 Hz, 3rd Bending mode

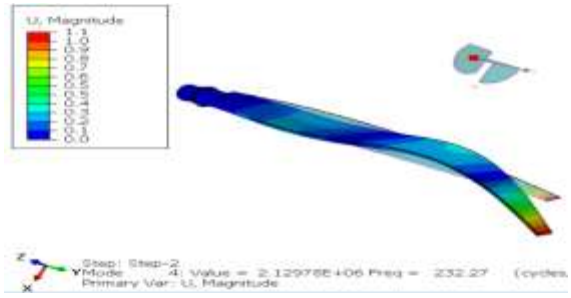

Fig -18: Carbon ud epoxy Mode 4:232.2 Hz, 3rd Bending mode

3.8 Modal analysis of propeller blade and comparison for Mode 5

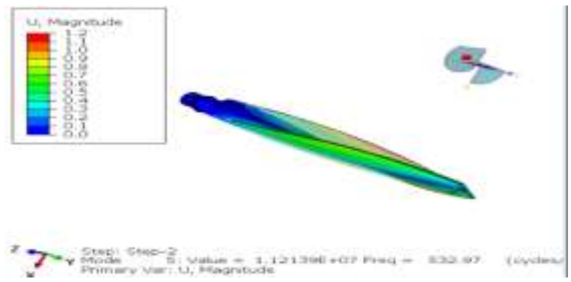

Fig -19: Aluminum Mode 5:533 Hz, 1st Twisting mode

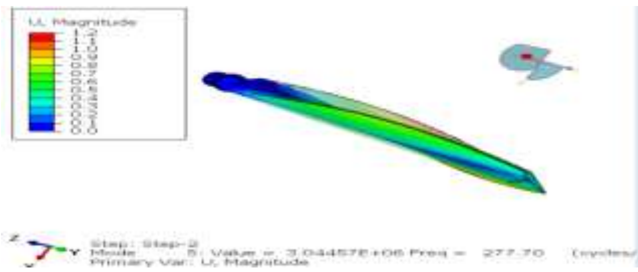

Fig -20: Carbon ud epoxy Mode 5:277 Hz, 1st Twisting mode

3.9 Modal analysis of propeller blade and comparison for Mode 6

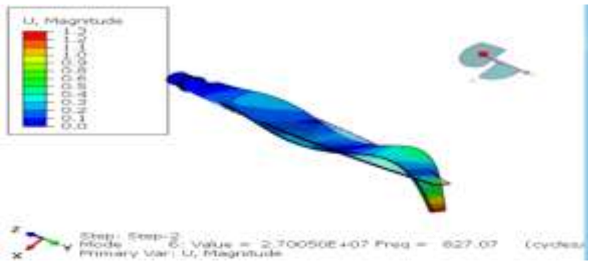

Fig -21: Aluminum Mode 6: 827 Hz, 4th Bending mode

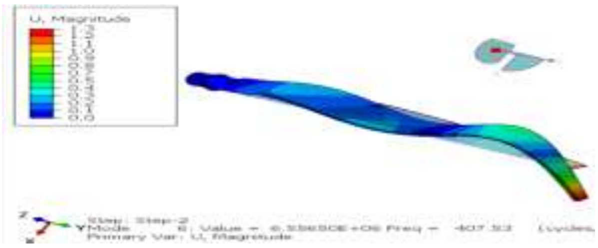

Fig -22: Carbon ud epoxy Mode 6:407.5 Hz, 4th Bending mode

3.10 Modal analysis of propeller blade and comparison for Mode 7

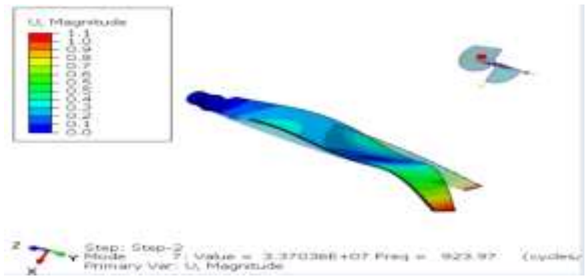

Fig -23: Aluminum Mode 7:924 Hz, 1st combined mode

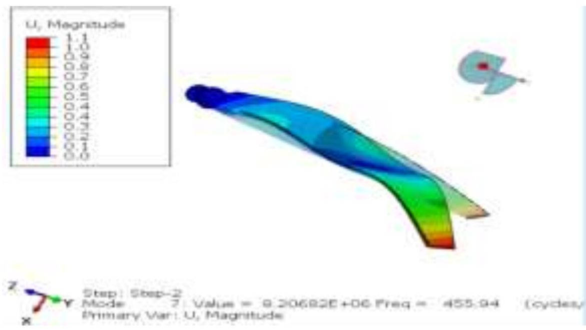

Fig -24: Carbon ud epoxy Mode 7:455.9 Hz, 1st combined mode

3.11 Modal analysis of propeller blade and comparison for Mode 8

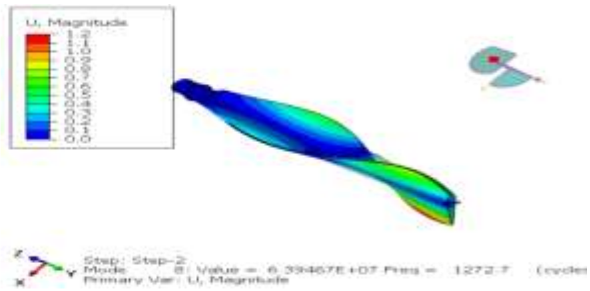

Fig -25: Aluminum Mode 8:1272.7 Hz, 2nd Twisting mode

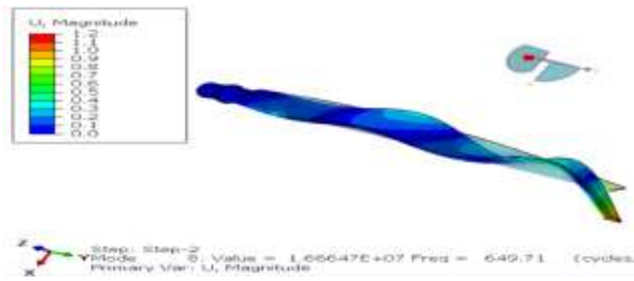

Fig -26: Carbon ud epoxy Mode 8:649.7 Hz, 2nd combined mode

4. CONCLUSION

The small aircraft propeller blade design validation is performed for strength, stability and vibration of the blade under the operating condition. The analysis is performed for two different materials; one is aluminum which is light weight. However it carries more weight than the composites. Also performance of composites is better when compared. The stress analysis shows maximum deflection of 22 mm in aluminum whereas 93 mm deflection is observed in the composite. This can be controlled with further design improvements in the blade design. The maximum stress in metal is 167 MPa whereas in composite it was found to be 94 MPa which is well within limits. Vibration analysis comparison shows that the first bending mode is at 47.3 Hz, whereas in composite its 23.1 Hz. This shows better vibration characteristics for blade when composite is used.

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